Solar Sense Node

IV-Curve group

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DESIGN SPECIFICATIONS

1. Battery powered
2. Fully portable
3. Battery life 8 hours or longer
4. The ability to measure solar panel temperature
5. The ability to measure solar panel inclination
6. The ability to measure solar irradiance
7. Transmit telemetry data to the main device or a computer
8. Wireless link range 100 meters or greater

Spec	Solar 03	Proposed solution
Battery life	24hours	30hours or higher
Tilt angle range & accuracy	1˚-90˚ ±(1.0% + 1°)	1˚-90˚ ±1˚
Module temperature range & accuracy	-40.0°C -99.9°C ±(1.0% + 1°C)	-55°C to +125°C ±0.5°C
Irradiance sensor range & accuracy	0-1400$\frac{W}{m^2}$ ±(1.0% + 3dgt)	To be determined

The following report illustrates the different parts of the project and why each one was selected.

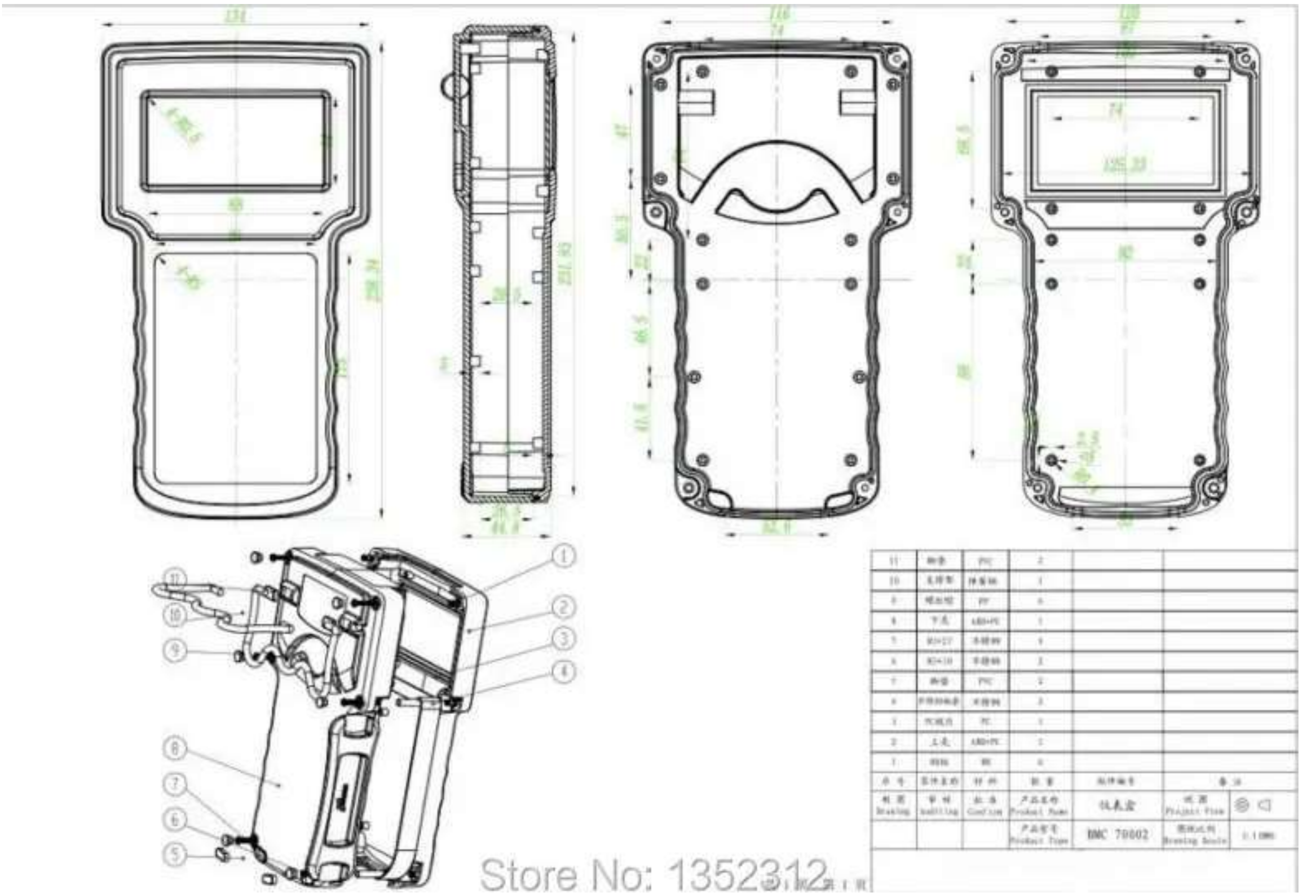
In addition to the information presented in this document, the link to the GitHub page of the project can be found here and below.

github.com/Alireza255/solar_sense_node

Choosing a box

The sensor box, being a portable device, requires a box with a form factor that suits the portable nature of the device.

The proposed box after careful research can be seen in the picture below:



Mechanical specifications:

- Material: ABS plastic
- Overall dimensions: 238 × 134 × 58 mm
- Weight: 310 g (excluding screws)
- Front panel cutout size: 88 × 44 mm

The ability to implement a screen and also buttons for user interface. There are also designated flat spots on the top and bottom for mounting connectors.

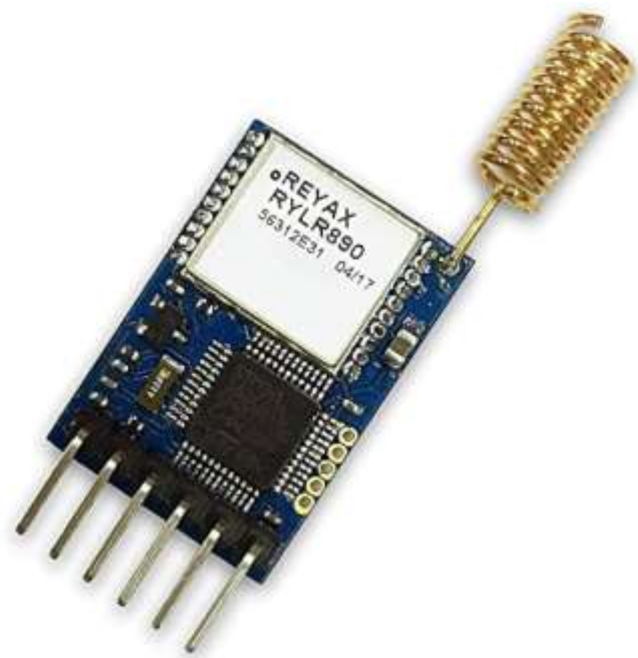
Choosing a wireless link

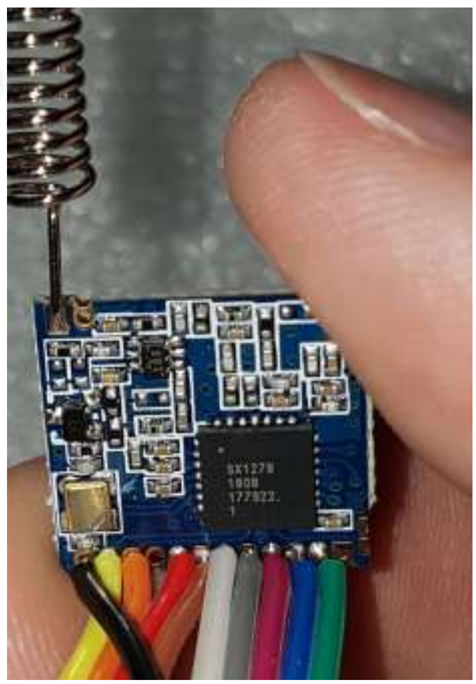
After careful consideration of the constraints and available options. LoRa was chosen for communication between the sensor box and the main box.

Why LoRa Was Selected

The sensor box system is battery powered and requires **maximum wireless range and high reliability under all environmental conditions**. LoRa was selected because it provides **exceptional range** while operating at very low power levels. Using chirp spread spectrum modulation, LoRa maintains reliable communication over long distances, including non-line-of-sight and interference-prone environments.

Unlike short-range technologies, LoRa is optimized for **low data rate, low duty-cycle sensor applications**, allowing long battery life without sacrificing range.





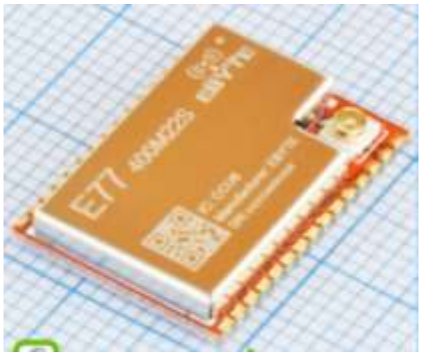
A comparison is made in the following table to illustrate the differences between the different communication links that are available for this application and why LoRa is the best for our application.

Technology	Typical Range	Power Consumption	Data Rate	Notes
LoRa	**500m-15 km**	**Very Low**	**Very Low**	**High link budget, robust in harsh environments**
Bluetooth	10-100 m	Very Low	Medium	Short range, sensitive to obstacles
Zigbee	50-200 m	Low	Low	Mesh required for long range
Wi-Fi	50-100 m	High	High	Not suitable for battery operation
Sub-GHz FSK	300-1000 m	Low-Medium	Low	Lower sensitivity than LoRa
Cellular	km+	Medium-High	Medium	Requires SIM and network dependent

It is important to note that the low data rate of the LoRa protocol will never be an issue because the amount of data that needs to be transmitted is extremely small.

Choosing a microcontroller

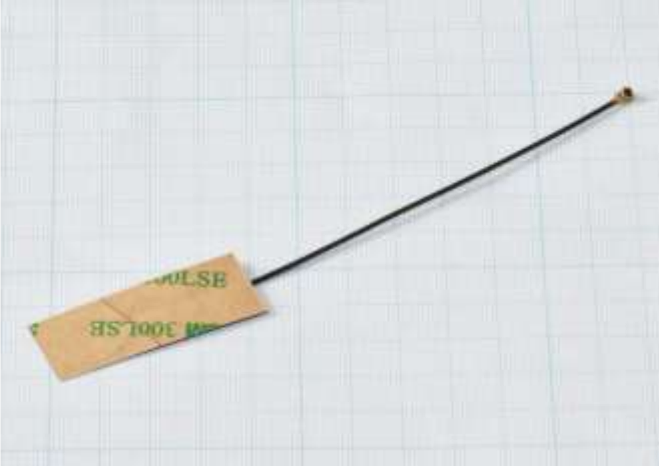
ARM microcontrollers, specifically those from ST-Microelectronics are very well suited for portable applications due to their low power requirements. Another reason being that ST offers a wide range of different microcontrollers (MCUs) for almost any application.
Research by the author indicates that microcontrollers with built-in radio links exist and considering the requirements of the project, **STM32WLE5CCU6** stands out as the perfect choice as it includes LoRa out of the box.
This eliminates the need to add a different module on the board, simplifying the design and freeing up more room for other components.



Ready-made modules are available which already include everything that is needed to run the microcontroller.
This will greatly simplify the design process.

Communication Antenna

Any radio link needs an antenna and LoRa is no exception. In general, two different types of antennae are suitable for our application, both of which can be seen in the figures below.



The antenna on the left is a patch antenna which can be installed within the device encloser itself while the antenna on the right is a monopole antenna. Both designed for 433MHz.
One drawback to the patch antenna is directionality. Which tends to be more focused in patch antennae. This makes communication harder since the orientation of the transmitter and reciver in relation to one another might not be ideal.

- While the benfit of the patch antenna is clear, testing with both antenna might be required in order to determine if the patch antenna is sufficient or not.

Power supply

In order to increase efficiency and improve battery life, great emphasis was put on having only one supply rail in the entire device and since the MCU, wireless link and most of the other components are powered by 3.3V, a decision was made from the very start to choose the remaining components in such a way that they will also be powered from 3.3V.
Regulating the battery voltage down to 3.3V using a linear regulator was chosen because of its simplicity and also the absence of much benefits if the design was to use a switching regulator.
Choosing the right regulator required careful consideration of multiple factors, one of them being the quiescent current which is a measure of the current draw when the output current of

the regulator is zero. This is extremely important as a low current draw when the micro controller is in sleep mode will mean a higher battery life when the device is not in use.

Now a question might arise; Why not just use a switch to allow the user to turn off the device? The answer lies in the real-time-clock of the microcontroller, which keeps time and date at the expense of a few uA of current. Safe to say it is completely worth it.

TLV743P 300-mA, Low-Dropout Regulator

1 Features

- Input Voltage Range: 1.4 V to 5.5 V
- Stable Operation With 1-μF Ceramic Output Capacitor
- Foldback Overcurrent Protection
- Packages:
  - SOT-23 (5)
  - X2SON (4)
- Very Low Dropout: 125 mV at 300 mA (3.3 V_{OUT})
- Accuracy: 1% (Typical), 1.4% (Maximum)
- Low I_Q: 34 μA
- Available in Fixed-Output Voltages: 1 V to 3.3 V
- High PSRR: 50 dB at 1 kHz
- Active Output Discharge

2 Applications

- Tablets
- Smartphones
- Notebook and Desktop Computers
- Portable Industrial and Consumer Products
- WLAN and Other PC Add-On Cards
- Camera Modules

3 Description

The TLV743P low-dropout linear regulator (LDO) is an ultra-small, low quiescent current LDO that sources 300 mA with good line and load transient performance. The device provides a typical accuracy of 1%.

The TLV743P is designed to be stable with a small output capacitor with a value of 1 μF. The TLV743P device provides foldback current control during device power up and enabling. This functionality is especially important in battery-operated devices.

The TLV743P provides an active pulldown circuit to quickly discharge output loads when the device is disabled.

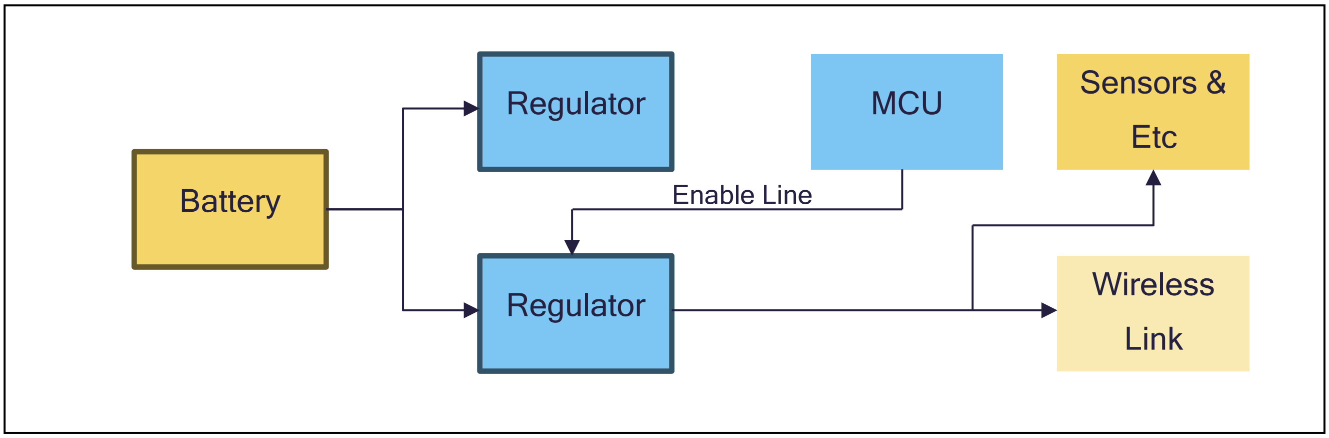
The TLV743P is available in standard DBV (SOT-23) and DQN (X2SON) packages.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TLV743P	SOT-23 (5)	2.90 mm × 1.60 mm
	X2SON (4)	1.00 mm × 1.00 mm

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

The chosen regulator can be seen on the picture above. This comes with the benefit of allowing the microcontroller to turn the regulator off which means we can turn sensors or any other parts of the circuit when needed to reduce power draw.



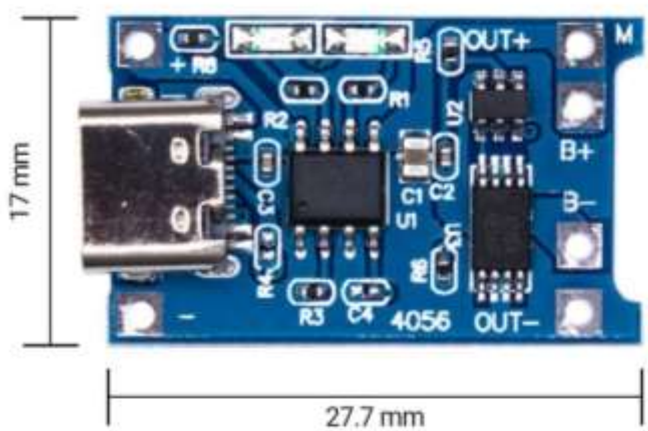
Battery and charging

Lithium polymer batteries in the common size 18650 were chosen to power the device due to their commonality.

Flat cells can also be used if the project runs into space constraints, which is unlikely.

Charging the battery will be done using a USB-C Li-Po battery charger module which will also provide the necessary voltage and current protections such as over-current, over-voltage and under-voltage protection.

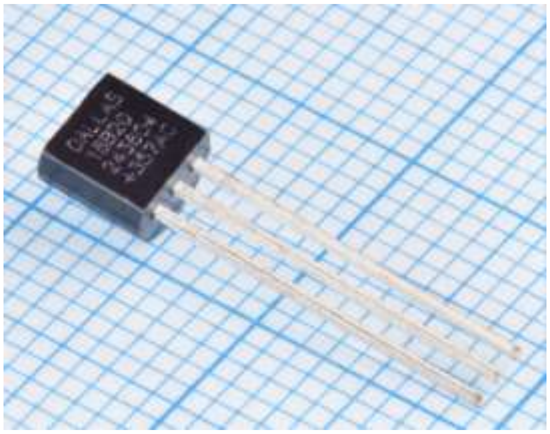
An off the shelf, proven solution was chosen instead of developing one from scratch, saving on time and increasing reliability.



Panel temperature sensor(s)

An interesting approach to panel temperature measurement was chosen. Instead of using analog sensors and having to deal with accuracy problems of analog circuits, noise susceptibility and most importantly and the current draw of analog sensors, the decision was made to use digital sensors.

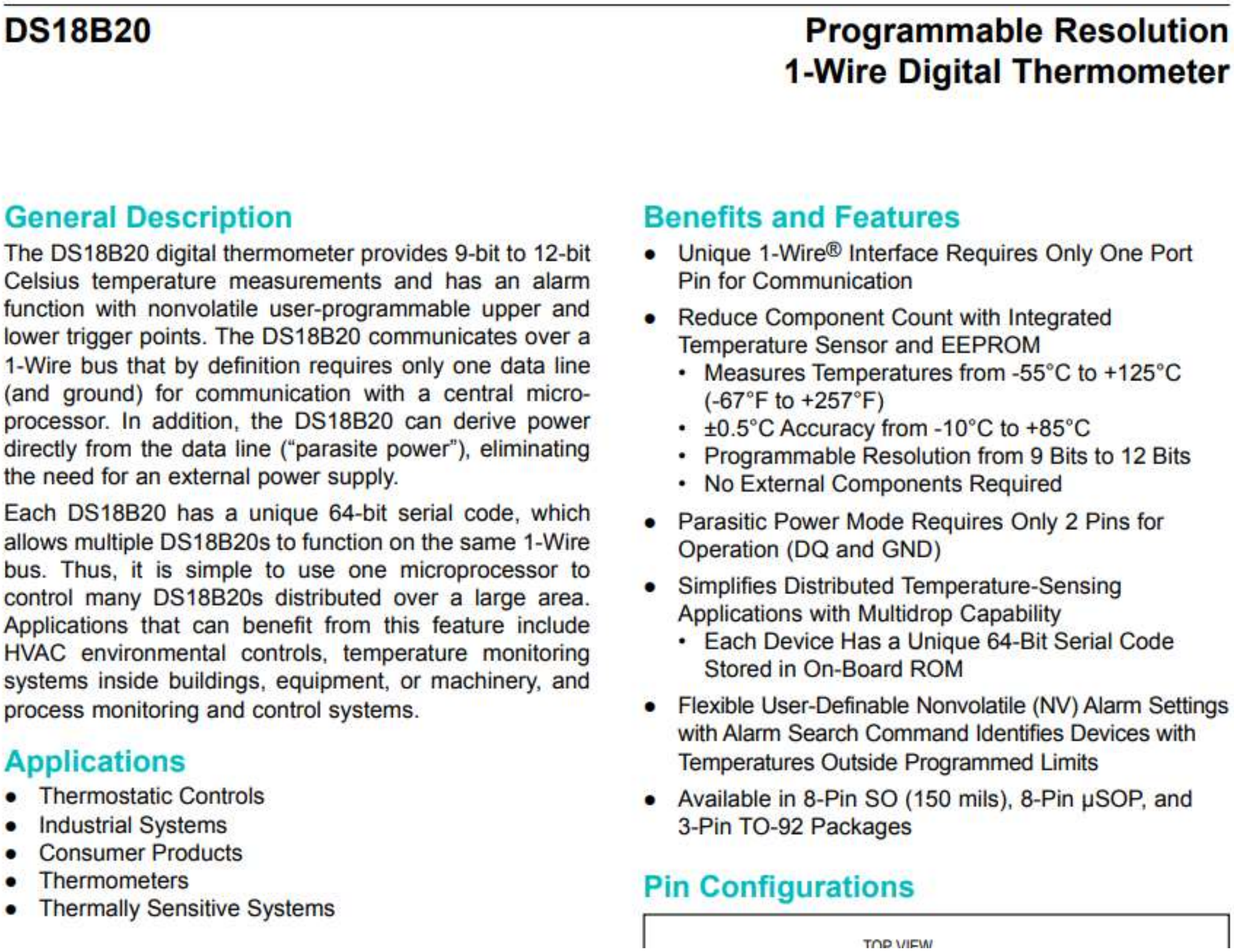
A very good digital sensor that can be used with just two wires is the famous DS18B20 by Maxim semiconductor.



This sensor provides the accuracy needed for our application.

Two wire mode can be be easily implemented by connecting supply pin of the sensor to ground, this action triggers the internal logic of the sensor to draw power form the data line!

Since the power demands of the sensor is really low, this is perfectly safe and works well in industrial applications.



DS18B20 — **Programmable Resolution 1-Wire Digital Thermometer**

General Description

The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. In addition, the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply.

Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. Thus, it is simple to use one microprocessor to control many DS18B20s distributed over a large area. Applications that can benefit from this feature include HVAC environmental controls, temperature monitoring systems inside buildings, equipment, or machinery, and process monitoring and control systems.

Applications

- Thermostatic Controls
- Industrial Systems
- Consumer Products
- Thermometers
- Thermally Sensitive Systems

Benefits and Features

- Unique 1-Wire® Interface Requires Only One Port Pin for Communication
- Reduce Component Count with Integrated Temperature Sensor and EEPROM
  - Measures Temperatures from -55°C to +125°C (-67°F to +257°F)
  - ±0.5°C Accuracy from -10°C to +85°C
  - Programmable Resolution from 9 Bits to 12 Bits
  - No External Components Required
- Parasitic Power Mode Requires Only 2 Pins for Operation (DQ and GND)
- Simplifies Distributed Temperature-Sensing Applications with Multidrop Capability
  - Each Device Has a Unique 64-Bit Serial Code Stored in On-Board ROM
- Flexible User-Definable Nonvolatile (NV) Alarm Settings with Alarm Search Command Identifies Devices with Temperatures Outside Programmed Limits
- Available in 8-Pin SO (150 mils), 8-Pin µSOP, and 3-Pin TO-92 Packages

Pin Configurations

TOP VIEW

The mentioned sensor is available in weather proof probes as well.

Each sensor has a unique 64-bit identification code which allows many sensors to be connected on the same bus. Both parasite power and multiple sensor capability are illustrated on the figure below.

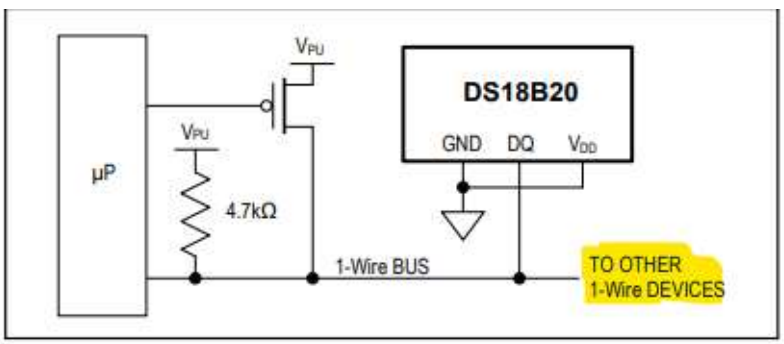
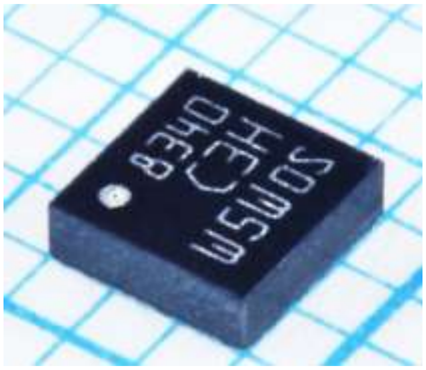


Figure 6. Supplying the Parasite-Powered DS18B20 During Temperature Conversions

Panel tilt angle measurement

Another important variable that commercial devices similar to the one we are building measure is panel tilt angle. Which can be measured using an accelerometer.

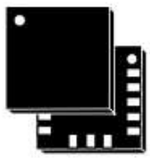
Since the accuracy requirements are not very strict, a simple accelerometer by the part number **LIS3DHTR** was chosen.



By using sensor data and calculating where the gravity acceleration vector is pointing, the angle of the device can be calculated.

MEMS digital output motion sensor:
ultra-low-power high-performance 3-axis "nano" accelerometer

Datasheet - production data



LGA-16 (3x3x1 mm)

Features

- Wide supply voltage, 1.71 V to 3.6 V
- Independent IO supply (1.8 V) and supply voltage compatible
- Ultra-low-power mode consumption down to 2 μA
- ±2*g*/±4*g*/±8*g*/±16*g* dynamically selectable full scale
- I^2C/SPI digital output interface
- 16-bit data output
- 2 independent programmable interrupt generators for free-fall and motion detection
- 6D/4D orientation detection
- Free-fall detection
- Motion detection
- Embedded temperature sensor
- Embedded self-test
- Embedded 32 levels of 16-bit data output FIFO
- 10000 *g* high shock survivability
- ECOPACK®, RoHS and “Green” compliant
- Display orientation
- Gaming and virtual reality input devices
- Impact recognition and logging
- Vibration monitoring and compensation

Description

The LIS3DH is an ultra-low-power high-performance three-axis linear accelerometer belonging to the “nano” family, with digital I^2C/SPI serial interface standard output. The device features ultra-low-power operational modes that allow advanced power saving and smart embedded functions.

The LIS3DH has dynamically user-selectable full scales of ±2*g*/±4*g*/±8*g*/±16*g* and is capable of measuring accelerations with output data rates from 1 Hz to 5.3 kHz. The self-test capability allows the user to check the functioning of the sensor in the final application. The device may be configured to generate interrupt signals using two independent inertial wake-up/free-fall events as well as by the position of the device itself. Thresholds and timing of interrupt generators are programmable by the end user on the fly. The LIS3DH has an integrated 32-level first-in, first-out (FIFO) buffer allowing the user to store data in order to limit intervention by the host processor. The LIS3DH is available in small thin plastic land grid array package (LGA) and is guaranteed to operate over an extended temperature range from -40 °C to +85 °C.

Table 1. Device summary

Solar irradiance sensor

The solar irradiance sensor used in the reference product Solar-03 made by HT Instruments is an external reference solar cell that is very well characterized and tested. Solar-03 then measures the current generated by the panel and correlates that to a solar irradiance number.

The irradiance sensor can be seen on the right which has internally stored calibration data which the Solar-03 uses to calculate the solar irradiance. The basic specs can be found in the table below.

- **Measuring range**: 100 ÷ 1400W/m^2
- **Basic accuracy**: ±3.0% reading
- **Type of cell**: Monocrystalline
- **FOV angle**: >160°
- **IP rating**: IP65 according to IEC/EN60529
- **Output connector**: custom 5-pin HT connector
- **Connection cable**: approx. 2m
- **Dimensions (WxDxH)**: 111x85x28mm
- **Weight**: 240g
- **Internally stored calibration parameters**

More time seems to be required in order to choose the right sensor. This is mainly the result of few available options if we decide to go the buying route and the difficulty of molding and characterizing a reference cell by ourselves if we decide to go the DIY route.