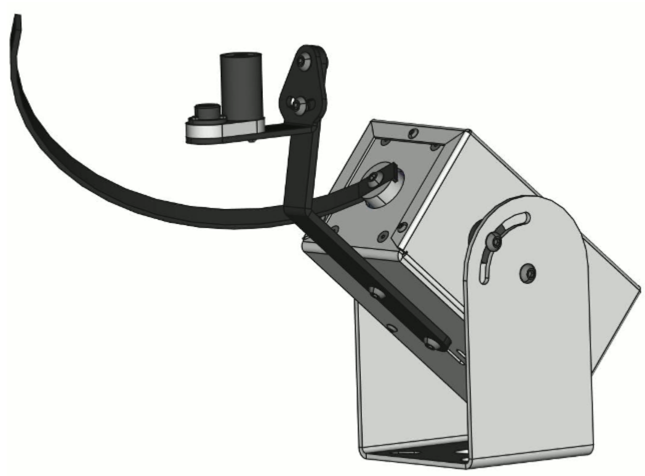


Irradiance

Irradiance RSR3

Introduction

The Irradiance RSR3 Rotating Shadowband Radiometer (TM) measures sunlight by momentarily shading a silicon photodiode pyranometer with a shadowband and computing global (GHI) and diffuse (DHI) horizontal irradiance and thus inferring direct normal irradiance (DNI). The RSR3 is a fully-integrated device powered by 12v and accessed with the industry-standard MODBUS RTU protocol.

Specifications

Specification	Value	Unit
Physical		
Length	15	Inch
Width	4	Inch
Height	11	Inch
Weight	3.5	Lbs
Electrical		
Power Voltage Min	11	V
Power Voltage Max	18	V
Power Current Standby	10	mA
Power Current Peak	1000	mA
Power Daily Budget	500	mAh
Standard Cable Length	6.5	Feet
Communications		
Communication	Modbus RTU RS-485	
Baud Rate	Default 19200 8E1; possible 1200-500,000.	bits per second
Address	Default last two digits of serial number; possible 1-254.	
Measurement Uncertainty		
GHI Daily Bias	2	% RMS
GHI RMS Noise	10	W/m^2 RMS 1m
GHI RMS Noise	5	W/m^2 RMS 1h
DNI Daily Bias	2	% RMS
DNI RMS Noise	10	W/m^2 RMS 1m
DNI RMS Noise	5	W/m^2 RMS 1h
DHI Daily Bias	5	% RMS
DHI RMS Noise	15	W/m^2 RMS 1m
DHI RMS Noise	10	W/m^2 RMS 1h

Safety

Risks while installing and servicing solar instrumentation such as RSR3s include:

- Falling. Sensors are typically installed on roofs, tripods, towers, or other elevated items. Users should select and utilize proper climbing and safety equipment for their installations.
- Electrocution. The RSR3 operates on 12V which is generally not dangerous, but in many installations higher voltages are present from mains power or photovoltaic strings. Users should ensure that all wiring is safely installed in compliance with applicable regulations.
- Lightning strikes. Ideal solar measurement locations are inherently prominently exposed locations with elevated risk. Users are advised against installing and servicing RSR3s when electrical storm activity is forecast.
- Physical injury. The band rotates without warning and can cause pinch or bruise injuries, especially to eyes and fingers. Users are advised to disconnect power before approaching an RSR3.
- Security. Appropriate physical security and signage should be utilized to exclude and warn unauthorized personnel.

Warranty & Support

The RSR3 is warranted for materials and workmanship for a period of two years starting the date of shipment by Irradiance.

Irradiance believes the performance claims to be accurate. However, Irradiance **does not warrant the accuracy of measurements** and will not be held liable for damages resulting from customer use of the data, including, but not limited to, business decisions made on the basis of measurements and industrial control system operations depending on measurements.

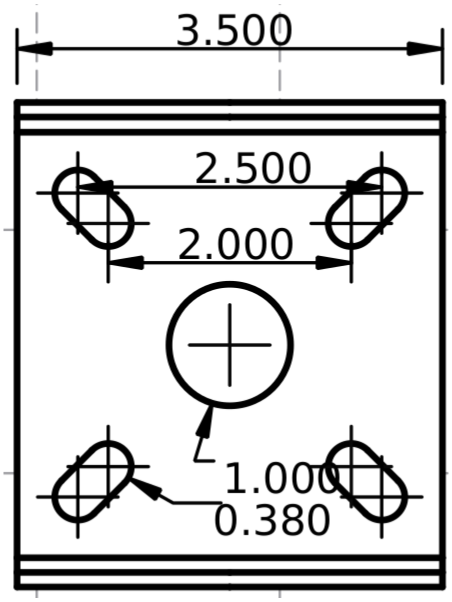
Please contact support@irradiance.com with support inquiries. Please do **not** return equipment before receiving authorization.

Contact

P.O. Box 381374
Cambridge, MA 02238-1374
United States of America
info@irradiance.com
http://www.irradiance.com/

Installation & Setup

Mounting



The RSR3 must be mounted securely. The pattern on its base is designed to be mounted to the top of a vertical pipe with a flange, or to a horizontal north/south or east/west pipe or strut channel rail using u-bolts. The mounting structure should be as nearly level as possible so minimal additional correction is required for mounting the RSR3 and other instruments.

The stability of the mounting platform affects the amount of effort required to keep the sensor level. A sensor on a concrete pad deeper than frost line may never require re-leveling; a sensor on a tripod on top of freezing/thawing ground may require frequent re-leveling.

The bolt pattern is shown at right. See "replacement parts" list for recommended hardware.

Alignment & Leveling

The RSR3 has two hex screws on each side securing the tilt axis and two hex screws on the pyranometer arm securing the roll axis. These should be tightened with a 5/32 hex key when the bulls-eye level next to the pyranometer is centered.

Horizon

The ideal site has clear horizons, especially near true east and west, so that direct solar measurements may be made when the sun is low in the sky. It is generally preferable to acquire the most complete dataset possible and simulate any shading in solar array fields, rather than situating the sensor as the panels would be shaded.

Lightning Protection

The RSR3 is not expected to survive a direct lightning strike. However, any lightning rod nearby and above it will influence its measurements. For that reason many users forego protection. If a lightning rod is to be installed, however, it should be on the polar side of the RSR3 (i.e. north of in the Northern Hemisphere) and painted flat black.

Vegetation

If the RSR3 is to be mounted in an area with vegetation, growth which might interfere with measurements may be deterred by staking a square of landscape fabric to the ground before installation.

Power

The RSR3 and its data logger require a continuous 12V power supply. This is most often provided with a solar panel and lead acid battery. For an RSR3 by itself we recommend a 10W solar panel and a 7AH battery; the a CR300 series logger's internal charge regulator may be used. For larger systems a larger panel and battery and separate regulator may be required.

The RSR3 is supplied with a 6.5' cable terminated with bare leads. Custom cables are available.

Cable Conductor Table				
Position	1	2	3	4
Wire Color	Black	White	Green	Red
Function	Ground	RS485-	RS485+	+12V

Data Interface

The RSR3 uses the MODBUS RTU protocol over RS-485. This is a 0v/5v differential signaling protocol tolerant of several volts of offset. RS-485 is capable of long range operation if twisted-pair cabling is used. The RSR3 may run at any baud rate between 1200 and 500000; default communication settings are 115.2k baud and address 1. See the table below for baud rate constants.

Baud Rate Table										
CONFIG_BAUD	0	1	2	3	4	5	6	7	8	9
Baud Rate	1200	2400	4800	9600	19,200	38,400	57,600	115,200	230,400	500,000

Programming

With default settings the RSR3 will rotate as required and output the present conditions in the main output registers. This can be achieved on a Campbell Scientific datalogger using Com1 connected to the RSR3 with CS Basic code as follows:

```
Public RSR3(88) As Long
Alias RSR3(1) = RSR3_GHI
Alias RSR3(2) = RSR3_DNI
Alias RSR3(3) = RSR3_DHI
Alias RSR3(4) = RSR3_POA
' See RSR3_MODBUS_REG.DLD

' Each minute, log the average main outputs.
DataTable (Main, 1, 10080)
  DataInterval (0, 1, Min, -1)
  Average(4, RSR3, FP2, 0)
EndTable

' Each hour, log a snapshot of the full register bank.
DataTable (RSR3, 1, 168)
  DataInterval(0, 1, Hour, -1)
  Sample(88, RSR3, Long, 0)
EndTable

' Each second, read the main register bank.
Scan(1, Sec, 0, 0)
  ModbusMaster(RC, Com1, 19200, 1, 3, RSR3, 1, 88, 2, 60, 1)
  CallTable(Main)
  CallTable(RSR3)
NextScan
```

Please note that the accuracy of the RSR3 has been evaluated with the control registers at their default values. Changing the control registers may affect accuracy and is strongly discouraged for non-research users.

Configuration

A block of CONFIG registers can be stored in non-volatile memory by writing 4321 to the register CONFIG_RW. These include the baud, address, and calibration registers. When the modbus registers for address and baud are changed, the changes take effect as soon as the modbus transaction finishes. It is strongly advised that address and baud be changed and the flash write command be sent via the new address/baud rate, to verify communications.

Plane of Array

In addition to direct (DNI), diffuse (DHI), and global (GHI), the RSR3 computes and outputs plane-of-array (POA) irradiance for a user-configurable array. At this time the only supported array type is fixed.

Please note that this is merely a calculation made available for user convenience and is not a separate measurement; it is possible to retroactively calculate POA irradiance for an arbitrary array based on logged DNI/DHI/GHI.

Cleaning & Maintenance

The RSR3 should be periodically serviced. The sensor should be cleaned with distilled water and a lint-free cloth and re-leveled if necessary.

There is not any specific required maintenance interval. Due to the translucent diffuser, RSR3s are much less sensitive to soiling than pyrheliometers and other instruments with glass windows. In some locations, periodic rainfall may be sufficient to keep an RSR3 free of substantial soiling; in other locations, it may not.

In general, the credibility of data files in substantially enhanced by complete maintenance logs attesting that the sensors were in good condition and operating properly during the measurement interval.

Calibration

The RSR3 contains a new Licor LI-200R pyranometer sensor with the Licor factory calibration number entered.

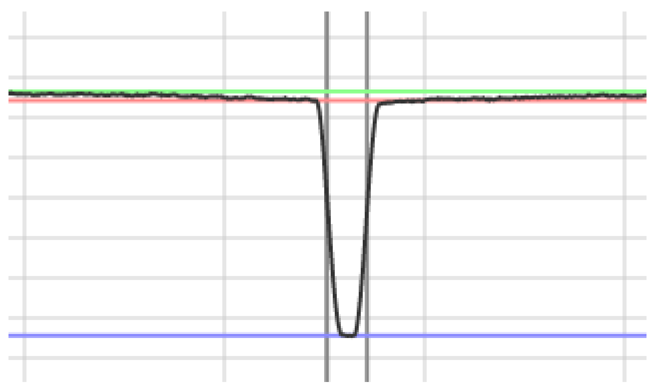
Irradiance recommends annual recalibration of each RSR3 and is capable of performing this service from March to September. Please contact support@irradiance.com.

Irradiance does not recommend most customers recalibrate their own RSR3s. However, the following guidance is provided:

- The RSR3 output should be compared to a superior reference instrument, ideally a pyrheliometer.
- Calibration by DNI is preferred; GHI is acceptable. DHI is not possible.
- Calibration should be performed on clear days with the sun high in the sky.
- At least a whole day of data should be used. If multiple days are used, equal weight should be placed on morning and afternoon data.
- After the RSR3's bias is determined, CONFIG_PYCAL1 should be scaled inversely proportionally and the value stored in non-volatile memory.

Theory of Operation

1. Each second the RSR3:
    - Increments its clock. If the clock must be set, the GPS is enabled and **FIXTIME** begins counting until the GPS provides a time, **YEAR-MONTH-DAY HOUR:MINUTE:SECOND**, and location **LATITUDE, LONGITUDE, ELEVATION** with **SATELLITES** >= 4. After this occurs the GPS is disabled and **SLEEPTIME** is set to 1800 seconds and begins counting down.
    - Uses NREL SOLPOS to calculate the position of the sun, **SOLAZM** and **SOLZEN** in 1/100th of degrees.
    - **GHI** is measured, and new values for **DNI** and **DHI** are inferred by proportionally scaling the last measured values.
    - Using those values and **CONFIG_ARRAZM** and **CONFIG_ARRZEN** computes **POA**
    - When **AUTOROTATE** is nonzero evaluate whether any rotation condition is active and if so set **ROTATE**:
        - Once every 10 minutes, regardless.
        - Once every minute during daylight, when GHI > 25.
        - Once every 30 seconds during sunlight, when DNI > 25.
        - When ABS(GHI - GHIROT) > 25.
2. When **ROTATE** becomes nonzero the RSR3 acquires data:
    - **ROT_MS** is zeroed and begins incrementing at 1 khz.
    - **COUNTER** is incremented.
    - **BANDPOS** is checked to determine rotation direction.
    - **MOTOR_MA_MAX** is reset to zero.
    - **BATT_MV_MIN** is reset to **BATT_MV**
    - **MOTOR** is set to +/- **SPEED**.
    - Motor accelerates according to **ACCEL**.
    - While the band is between the two sensors (i.e. **BANDPOS** == 0) values from **TIA1** are recorded to **VECTOR**.
    - When the opposite limit is reached, data recording ceases, and the band decelerates at the same rate while the scan is processed.
3. Initial data processing is as follows:
    - If the band rotated backwards, the data is reversed.
    - The data is downsampled to **AUTOSIZE** samples.



4. Scan reduction:
    - **SHADOW_CENTER** and **SHADOW_WIDTH** are determined by using a band-width box filter to find the minimum and refining by determining half-value points. (gray lines)
    - **SHADOW_VALUE** (blue line) is found at the center of the shadow; **NEAR_VALUE** (red line) is found exactly two shadow radii on either side of the shadow; and **LINE_VALUE** (green line) is found by interpolating a line from the rotation endpoints at the moment of shadow. These values are in A*1e-8 i.e. hundredths of uA.
5. Raw outputs are computed from:
    - **GHIRAW** = CONFIG_PYCAL1 * (LINE_VALUE)
    - **DNIRAW** = CONFIG_PYCAL1 * ((NEAR_VALUE - SHADOW_VALUE) / COS(SOLZEN))
    - **DHIRAW** = CONFIG_PYCAL1 * (LINE_VALUE - (NEAR_VALUE - SHADOW_VALUE))
6. Corrections are applied:
    - AVG(GHI/GHIRAW) -- the 3% average GHI correction necessary to enter LICOR calibration numbers.
    - **RFAM**: Increased pyranometer response due to reddening at high airmass.
      This has been measured outdoors using pyranometers in collimating tubes compared to pyrheliometers.
    - **RFZ**: Increased pyranometer response at certain high zenith angles. This has been measured in laboratory conditions using pyranometers rotated under artificial light.
    - **RFT**: Increased pyranometer response at higher temperatures.
    - **RFDA**: Reduced pyranometer response to pure blue sky.
    - **RFCI**: Reduced pyranometer response due to weighted clouds/blue sky.
7. Rotation outputs are computed and copied to the main output registers:
    - **DNIROT** = DNIRAW * RFT * RFZ * RFAM
    - **DHIROT** = DHIRAW * RFT * RFCI
    - **GHIROT** = DHIROT + DNIROT * COS(SOLZEN)
8. Raw scan data may be downloaded.

- The 100 samples surrounding the shadow are copied to a special buffer.

9. Also
   - If **AUTOSPEED** is nonzero, then **SPEED** is adjusted to result in that many raw samples.

MODBUS Registers

Please note that the modbus register map is subject to change in the future if features are added. Consult the documentation shipped with your unit.

Each RSR3 is shipped with the LiCor factory calibration value of its installed pyranometer programmed into CONFIG_PYCAL1. For LI200R-type pyranometers these are in the range of ~1400, which would correspond to 14.00 W/m^2/uA.

REG	NAME	UNITS	DEFAULT	DESCRIPTION
Main output registers				
These are updated continuously by default				
0	GHI	W/m^2		Global Horizontal Irradiance
1	DNI	W/m^2		Direct Normal Irradiance
2	DHI	W/m^2		Diffuse Horizontal Irradiance
3	POA	W/m^2		Plane of Array Irradiance
GPS/Clock registers				
These values are updated continuously				
4	YEAR	year		GPS Year
5	MONTH	month		GPS Month
6	DAY	day		GPS Day
7	HOUR	hour		GPS Hour
8	MINUTE	minute		GPS Minute
9	SECOND	second		GPS Second
10	LATITUDE	0.01*Deg		GPS Latitude
11	LONGITUDE	0.01*Deg		GPS Longitude
12	ELEVATION	m		GPS Elevation AMSL
13	SATS			GPS Satellites (-1 when off)
14	FIXTIME	sec		Time to fix
15	SLEEPTIME	sec		Time until wakeup
SOLPOS computed registers				
These values are computed continuously				
16	SOLAZM	0.01*Deg		Solar Azimuth Angle; true
17	SOLZEN	0.01*Deg		Solar Zenith Angle; refracted
18	ARRANG	0.01*Deg		Solar Plane Of Array Angle
19	AMGEOM			Airmass; geometric
20	ELVPRESS	hPa		Elevation inferred pressure
21	AMPRESS			Airmass; pressure corrected
Raw sensor output registers				
These values are measured continuously				
22	TIA1	0.01*uA		Present transimpedance amp #1 value
23	TIA2	0.01*uA		Present transimpedance amp #2 value
24	TEMPBOARD	C		Temperature of control board
25	TEMPPY	C		Temperature of sensor platform
26	BATT_MV	mV		Power supply voltage
27	MOTOR_MA	mA		Motor current
28	EXT1_MV	mV		External voltage 1
29	EXT2_MV	mV		External voltage 2
Rotation status registers				
These values are updated during and after rotation only				
30	MOTOR_MA_MAX	mA		Max RSR3_MOTOR_MA during rotation
31	BATT_MV_MIN	mV		Min RSR3_BATT_MV during rotation
32	BANDPOS			Band position sensor. -1=CCW 0=Middle +1=CW
33	ROTCOUNT			Rotation counter

34	ROTTIME	mSec		Latency from rotation trigger to data ready
Rotation control registers				
These registers control rotation				
35	ROTATE	bool		Rotation trigger/status
36	AUTOROTATE	bool	1	Trigger rotation automatically
37	AUTOSPEED		2100	Target # samples for speed adjustment
38	AUTOSIZE		2000	Output # samples for downsample
39	ADCAVG	sample	5	ADC averaging mode
40	SPEED	PWM256	224	Adjusted rotation speed
41	ACCEL	PWM256	3	Motor acceleration limit
42	MOTOR	PWM256		Present motor speed
Rotation detailed output registers				
These values are updated after rotation				
43	SCAN_RAWSIZE	index		Rotation samples acquired; negative if reversed
44	SCAN_SIZE	index		Rotation samples size; after downsampling
45	SCAN_MEAN	0.01*uA		Mean value of scan
46	SCAN_MIN	0.01*uA		Minimum value of scan
47	SCAN_ORD01	0.01*uA		1% order statistic of scan
48	SCAN_ORD05	0.01*uA		5% order statistic of scan
49	SCAN_ORD50	0.01*uA		50% order statistic of scan
50	SCAN_ORD95	0.01*uA		95% order statistic of scan
51	SCAN_ORD99	0.01*uA		99% order statistic of scan
52	SCAN_MAX	0.01*uA		Maximum value of scan
53	SCAN_MINPOS	index		Index of minimum
54	SCAN_MAXPOS	index		Index of maximum
55	SHADOW_CENTER	index		Shadow center index
56	SHADOW_WIDTH	index		Shadow width
57	SHADOW_VALUE	0.01*uA		Value at bottom of shadow
58	NEAR_VALUE	0.01*uA		Value near shadow
59	LINE_VALUE	0.01*uA		Value of line at shadow
60	COSZEN	0.0001		Cosine zenith angle
61	GHIRAW	W/m^2		Uncorrected global horizontal irradiance
62	DNIRAW	W/m^2		Uncorrected direct normal irradiance
63	DHIRAW	W/m^2		Uncorrected diffuse horizontal irradiance
64	RFAM	0.0001	10000	Airmass responsivity
65	RFZ	0.0001	10000	Zenith angle responsivity
66	RFT	0.0001	10000	Thermal responsivity
67	RFDA	0.0001	10000	Clear-sky diffuse responsivity
68	RFCI	0.0001	10000	Weighted diffuse responsivity
69	GHIROT	W/m^2		Rotation Global Horizontal Irradiance
70	DNIROT	W/m^2		Rotation Direct Normal Irradiance
71	DHIROT	W/m^2		Rotation Diffuse Horizontal Irradiance
Configuration stored registers				
These values can be stored in non-volatile memory				
72	CONFIG_RW			Configuration LOAD=1234 SAVE=4321
73	CONFIG_BAUD		7	Baudrate index
74	CONFIG_ADDR		1	Modbus address
75	CONFIG_SERIAL		0	Serial Number
76	CONFIG_PYSN1			Pyranometer #1 serial number
77	CONFIG_PYCAL1	W/m^2uA100	1400	Pyranometer #1 calibration
78	CONFIG_PYSN2			Pyranometer #2 serial number
79	CONFIG_PYCAL2	W/m^2uA100	1400	Pyranometer #2 calibration
80	CONFIG_ARRTYPE		0	Array tracking type; 0:fixed
81	CONFIG_ARRAZM	0.01*Deg	0	Array azimuth angle
82	CONFIG_ARRZEN	0.01*Deg	0	Array zenith/tilt angle
83	CONFIG_ALBEDO	0.0001	1000	Ground albedo
Register copy utilities				

May be used to perform internal memory copy operations				
84	**REGCPY1_DST**			**Register copy #1 destination**
85	**REGCPY1_SRC**			**Register copy #1 source**
86	**REGCPY1_NUM**			**Register copy #1 number**
87	**REGCPY2_DST**			**Register copy #2 destination**
88	**REGCPY2_SRC**			**Register copy #2 source**
89	**REGCPY2_NUM**			**Register copy #2 number**
Scan Array Data				
100	SCANCENTERDATA	0.01*uA		Center data
200	FREESPACE1	0.01*uA		Free space
1000	SCANDATA	0.01*uA		Scan Vector
4000	FREESPACE2	0.01*uA		Free space

Replacement Parts / Recommended Accessories

Head Unit Fasteners	McMaster-Carr
18-8 Stainless Steel Button Head Hex Drive Screw, 1/4"-20 Thread Size, 1/2" Long	92949A537
Abrasion-Resistant Cushioning Washer for 1/4" Screw Size, 0.25" ID, 1" OD	90131A305
Nylon Plastic Washer for 1/4" Screw Size, 0.312" ID, 0.5" OD	95606A430
Hex L-Key, 5/32" Size, 2-11/16" Overall Length	7122A21
18-8 Stainless Steel Pan Head Phillips Screw, 6-32 Thread, 1/4" Long	91772A144

Cable Connectors	Campbell Scientific	Conxall	DigiKey
CONN PLUG FEMALE 4POS SOLDER CUP		6382-4SG-522	SC3234-ND
CABLE FEMALE STRAIGHT TO WIRE LEAD 4POS 6.56'		CA62804S07990	SC2358-ND
CABLE FEMALE RIGHT-ANGLE TO WIRE LEAD 4POS 6.56'		CARA62804S07990	SC2369-ND
CONN RCPT MALE 4POS SOLDER CUP		7282-4PG-300	SC1276-ND
CONN PLUG FMALE 4POS SOLDER CUP		6382-4SG-522	SC3234-ND
CONN DUST COVER BLACK		6295	SC1397-ND
22AWG 2PR Twisted Pair Shielded Santoprene Cable	9720		
In general, for short distances almost any cable will suffice. For longer distances, the signal pair should be twisted and the the power pair should be appropriately enlarged.			

Flange Mounting		
Description	**Hollaender**	**McMaster-Carr**
Aluminum Slip-on Fitting, Round Flange Rail End for 1-5/8" Rail OD	42-7	4698T146
18-8 Stainless Steel Hex Head Screw, 5/16"-18 Thread Size, 1" Long		92240A583
18-8 Stainless Steel Hex Nut, 5/16"-18 Thread Size		91845A030

U-Bolt Mounting	
Description	**McMaster-Carr**
304 Stainless Steel U-Bolt, 5/16"-18 Thread Size, 1-3/4" ID, 2-11/16" Height	8896T127
Strut Channel, Slotted Hole, Black Powder-Coated Steel, 6 Feet Long	3310T766

Communications	
Description	**Amazon**
Uxcell RS232 to RS485 Communication Data Converter Adapter	B005FOOVLA
Irradiance has tested this device successfully between an RSR3 and a CR300 datalogger's RS-232 port. The CR300 datalogger serial port does **not** provide sufficient power on control lines for line-powered adapters and some similar products require regulated 5v inputs. This unit can take 12v in. Be advised that it consumes 10ma.	