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PICOSTRAIN

Application Note

Design Guidelines for Building a Solar Kitchen Scale

24 March 2010

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Design Guidelines for Building a Solar Kitchen Scale with PS081

1 Foreword

In 2008 acam presented a solar body scale with PS08 for demonstration and evaluation. This was the first real solar driven scale that used strain gages as sensors. The circuitry was optimized for PS08 and according to the knowledge we had about the edge conditions of body scales, e.g. lighting conditions, size of solar panel, etc. Today, in July 2009, we have the PS081, the revised version of PS08.

Now, with the new circuitry, we also introduce the first solution available for solar driven kitchen scales based on strain gage sensors. The scale we introduce is a true solar scale without additional backup battery. It is only driven by solar power and is strictly designed to lowest power consumption by using newest PICOSTRAIN technology.

The kitchen scale uses the same proven start-up circuit as the body scale described earlier. This circuit guarantees a save and fast start-up from darkness. In this paper we point out the specials of solar driven scales with PICOSTRAIN. It includes a complete schematic with proven layout and a lot of information on what is needed for a fast and successful development.

For first tests, the evaluation PCB can be directly driven with the PicoProg device. First evaluation of the performance and current consumption can be done with a PC. For this first evaluation level we deliver sample configurations for the PS081 for the different resolution settings (2,000 divisions, 3,000 divisions and 5,000 divisions)

Please stick close to our recommendations, especially for the parts of the schematic and the section of the layout which drives the strain gages and at the power-up circuit. The circuitry was optimized close to the maximum possible and works well when being built up as recommended. Even small changes on the critical components can lead to malfunction of the whole scale!

2 Resolution & Supply Current

2.1 Sensor Type

In this paper we discuss options for resolution and current consumption that are all based on a **single point load cell** with 1 mV/V F.S. **We strongly recommend this type of load cell**.

Although quattro scales are more and more popular, they show two significant disadvantages for solar applications which cannot be neglected:

- Reduced excitation of 0.5 mV/V F.S. in combination with resolution of up to 5,000 Div. is very critical
- Longer unshielded wires

The excitation of a quattro load cells is approximately half the excitation of a center point load cells. The reason is to avoid an overload of the sensor. This leads to a significantly higher current of the quattro scale at the same resolution, because PICOSTRAIN needs to measure longer (bigger sample size / higher AVRate) to get the same resolution as with a center point load cell.

The 4 load cells of the quattro scale are connected with unshielded wires to the electronic. These 4 long wires introduce additional noise to the measurement. This, too, makes it necessary to increase the samples size / AVRate and, in consequence, the current of the scale.

These two facts lead to a minimum operating current for a 5 kg / 1 g kitchen scale with 0.5 mV/V F.S. excitation and 1 kOhm load cells of approximately 150 µA – too much for a solar driven scale.

A bathroom scale with typical 1,500 divisions at 1 mV/V needs only 1/6 of the resolution of a kitchen scale with 5,000 divisions. Therefore, it is possible to drive this kind of scale by solar power with a current of 15 µA.

2.2 Resolution, Current Consumption, Update Rate.

With a PS081 based electronic it is possible to design a solar driven kitchen scale with

2 Resolution & Supply Current

up to 5,000 divisions at 1 mV/V and a reasonable current consumption. With the same electronic also other resolution requirements can be selected only by changing the appropriate register settings in PS081. Depending on the requested resolution, we have different working currents – the lower the resolution the lower the supply current.

The following values are based on an update rate of 3 Hz and the usage of a median 5 filter. With this filter type the measurement value is typically stable within 1 sec. after a load jump. A configurable median filter is implemented as hardware routine in the PS081.

Remark: PS081 supports an easy variation of the current by adjusting the update rate in the software. The reason is that with PICOSTRAIN the operating current depends strongly on the update rate. With an intelligent software it's possible to switch the scale to higher update rates if necessary and also to lower ones when it is not needed. This offers a flexible method to give the user maximum performance when it is needed with always a good operating current in average.

Example:

- 1 Hz update rate with lower resolution in sleep mode (Auto-On functionality)
- 2 Hz update rate if no load change is detected within some seconds
- 5 Hz update rate if the load changes

Based on 3 Hz update rate and a 1 kOhm load cell with 1 mV/V F.S. the following total operating currents can be achieved:

Resolution	Total operating current
2,000 Div.	16 µA
3,000 Div.	22 µA
5,000 Div.	40 µA

2.3 Operating Mode

For the operating mode of the solar kitchen scale we recommend the "Stretched Mode". With this mode you get the best behavior on load changes, because the sampling of the

2 Resolution & Supply Current

values is distributed over the complete measurement time. For more information about this mode please refer to PS081 manual or our solar white paper (WP001). In this paper, all values like configuration register settings, schematics etc. are based on stretched mode.

2.4 Half bridge Connection

There is an additional possibility to reduce the current in case a half bridge connection is used. The 4 strain gage resistors can be connected as shown in figure 1. With PICOSTRAIN there is no need to build a fullbridge. A halfbridge is sufficient. PICOSTRAIN does not loose excitation with a halfbridge connection as AD-solutions do. If all 4 strain gage sensors are on one side of the load cell it is very easy to wire them as a halfbridge.

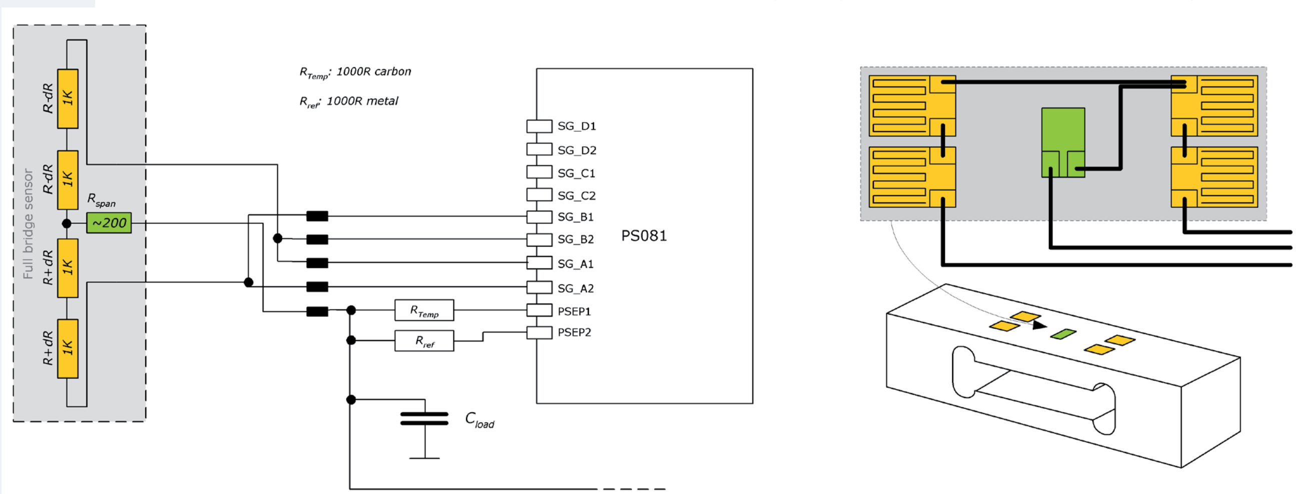


Figure 1: Hallf bridge connection

The advantage of this kind of connection is the doubled strain gage resistance (e.g. to 2 kOhm with 1 kOhm strain gages) and therefore a reduced operating current. In case of 2 kOhm the charging capacitor C1 can be reduced to 100 nF.

With this kind of connection and the same conditions as in the former example we achieve the following operating currents:

Resolution	Total operating current
2,000 Div	14 µA
3,000 Div.	18 µA
5,000 Div.	32 µA

Especially at higher resolution this gives advantages in current consumption. At lower resolution, other issues than the strain gage current get dominant (e.g. LCD, oscillator) and therefore the advantage is lower.
As a disadvantage, there is no possibility to work with TKGain and TKOffs. If the load cell has a Rspan resistor, this resistor has to have the correct value. It cannot be adjusted by software.

3 Circuit Description

All described sub-functions refer to the schematic which is attached in the appendix.

3.1 Power-Up Circuit

A proven power-up circuit is required to enable at good start-up behavior of the scale when it comes from darkness. This will happen every day. A solar panel delivers only a few microampere at poor light conditions and still has to start up the circuit.

The power-up circuit of the schematic is optimized for this task. To start up the scale it needs only about 3 µA @ 3.6 V. This can be achieved even with 'really' bad lighting conditions.

Short description of the function:
Coming from total darkness, all capacitors are discharged and the output of U5 is high-Z. The input voltage of U4 is zero. PS081 is not supplied by voltage.

If light is switched on, the current from the solar panel charges C17 and supplies the voltage detection. The voltage detection (R7,R14,Q1,U3) is dimensioned so that U3 switches when the voltage at C17 passes 3.5 V. At that moment, the output of U5 leaves high-Z and goes to the voltage of C17. U4 is supplied with 3.5 V and regulates to 2.5 V for the PS081. PS081 begins to work. Because all capacitors behind VCC_R have now to be charged to the voltage at C17, this voltage drops down as only C17 can supply the necessary current. The solar panel is to weak for such a high current pulse. The voltage at C17 must not be lower than 2.55 V. Otherwise U4 cannot regulate 2.5 V

3 Circuit Description

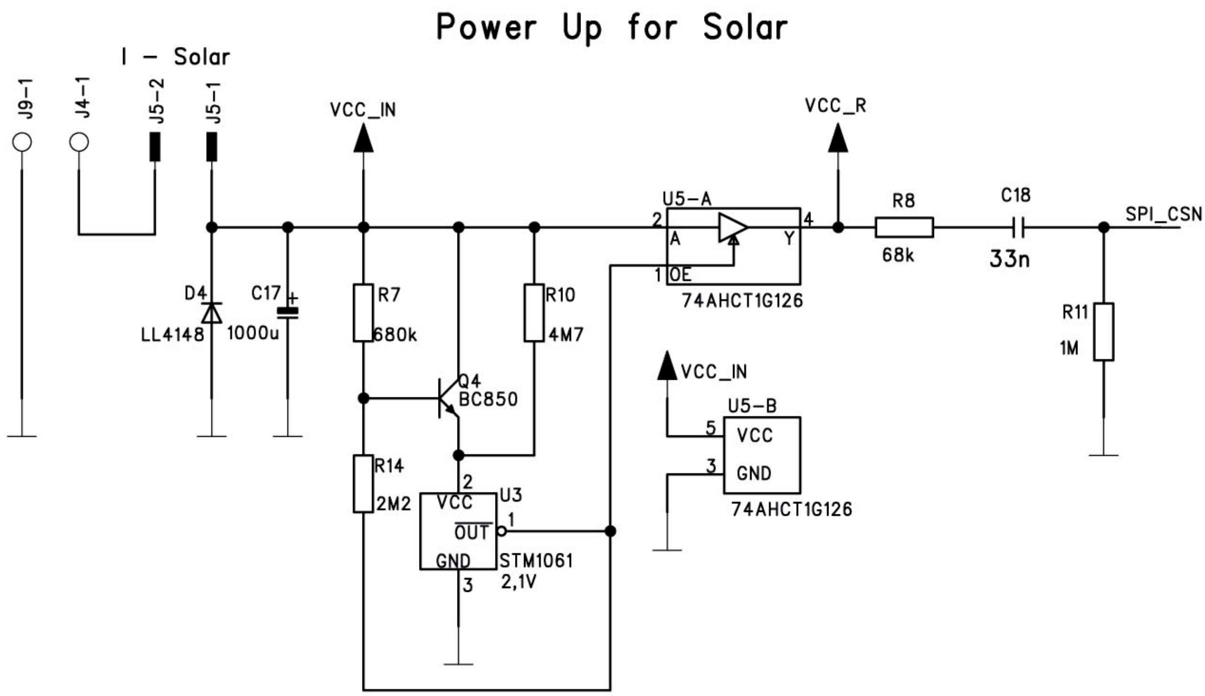


Figure 2

for the PS081. C17 is also the buffer capacitor for low light situation. With the selected dimension under very bad light condition (20 Lux) the scale can operate for minimum 1 minute if it is well charged before. Therefore 1000 µF is the recommended value for C17 (minimum 680 µF).

Avoid to go below 680 µF. The circuit cannot start up if C17 is too low. The circuit will work with higher values, too, but the start-up time from darkness will increase because the charging time for C17 increases.

With this circuit it is possible to have a quick start-up behavior and a safe start-up even at very dark light conditions.

3.2 Start-Up Time from Darkness

Light behavior in a typical kitchen:

The lighting conditions in a kitchen tremendously differ by the situation. It can range from 30 Lux in a darker part of the kitchen and no daylight and can go up to 50,000 Lux at

3 Circuit Description

the window when the sun is shining.

At weak lighting conditions the main part of the start-up time of the scale is the charging time of C17. At sunlight conditions (20,000 Lux) the solar panel supplies about 5 mA of current and the charging time of C17 is below 1 second and can be neglected. At bad lighting conditions the charging of this capacitor may need several minutes and is the dominating part of the complete start-up time.

The following graph shows the start-up time of the scale from totally darkness up to full operation. The calculation refers to a C17 value of 1000 µF and a solar panel which delivers 50 µA @ 200 Lux.

In this time 6 seconds Are included for first offset generation at the beginning.

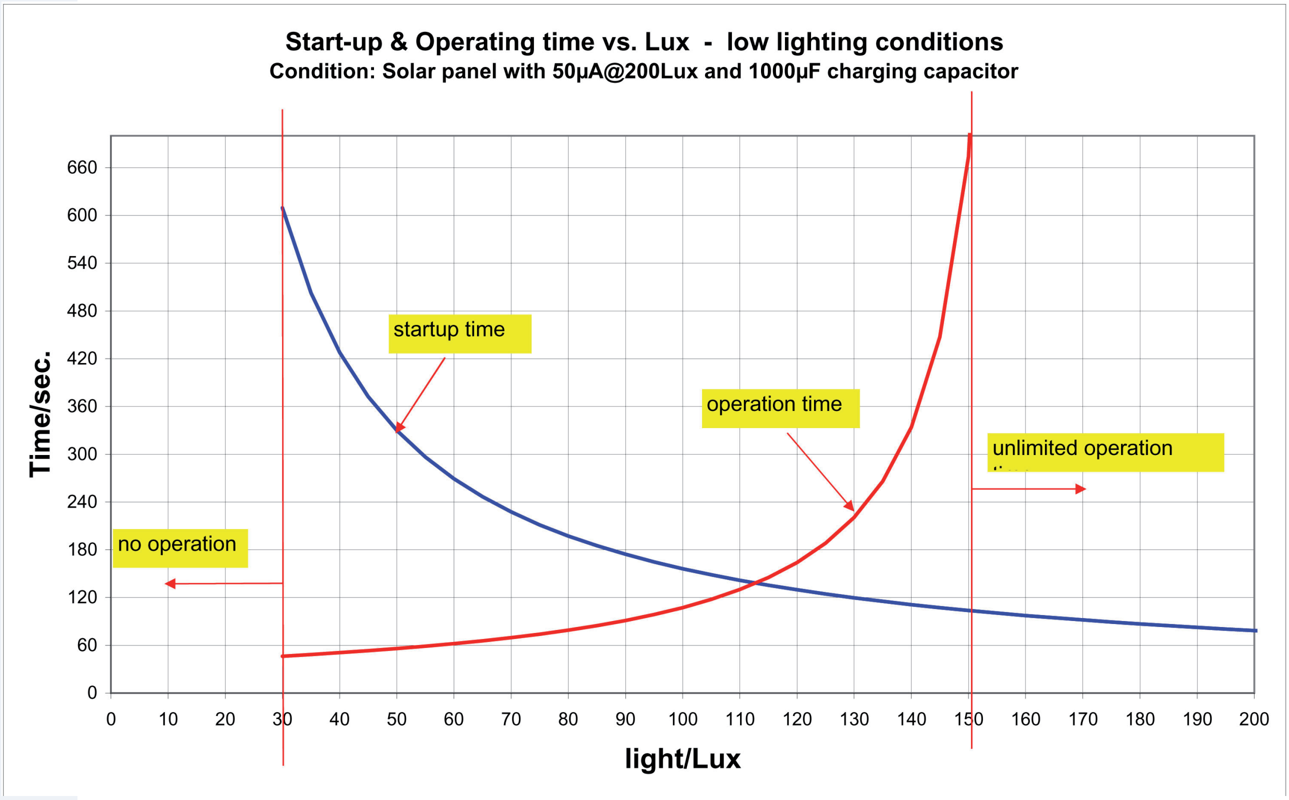


Figure 3

3 Circuit Description

Figure 3 shows the low light behavior of the scale at poor lighting conditions. As shown by the blue grapg, the scale will also start a very bad lighting conditions down to 30 Lux, but then it needs about 10 minutes to start up if C17 is totally discharged.

The red graph shows the possible operating time at the given light for the 5,000 divisions version of the scale. At lower light, below approximately 150 Lux, the operating time of the scale is limited because the solar panel cannot deliver the needed current (40 µA). At the lower operating limit (30 Lux) the scale can work for approx. 45 sec. if the 1000 µF charging capacitor is charged to 4.2 V

Figure 4 shows the situation at good lighting conditions from 200 Lux to 1000 Lux. The start-up time significantly decreases and the time for offset generation (6 seconds) gets more and more dominant. At such good lighting conditions the scale has continuous operation capability. The operation time is unlimited.

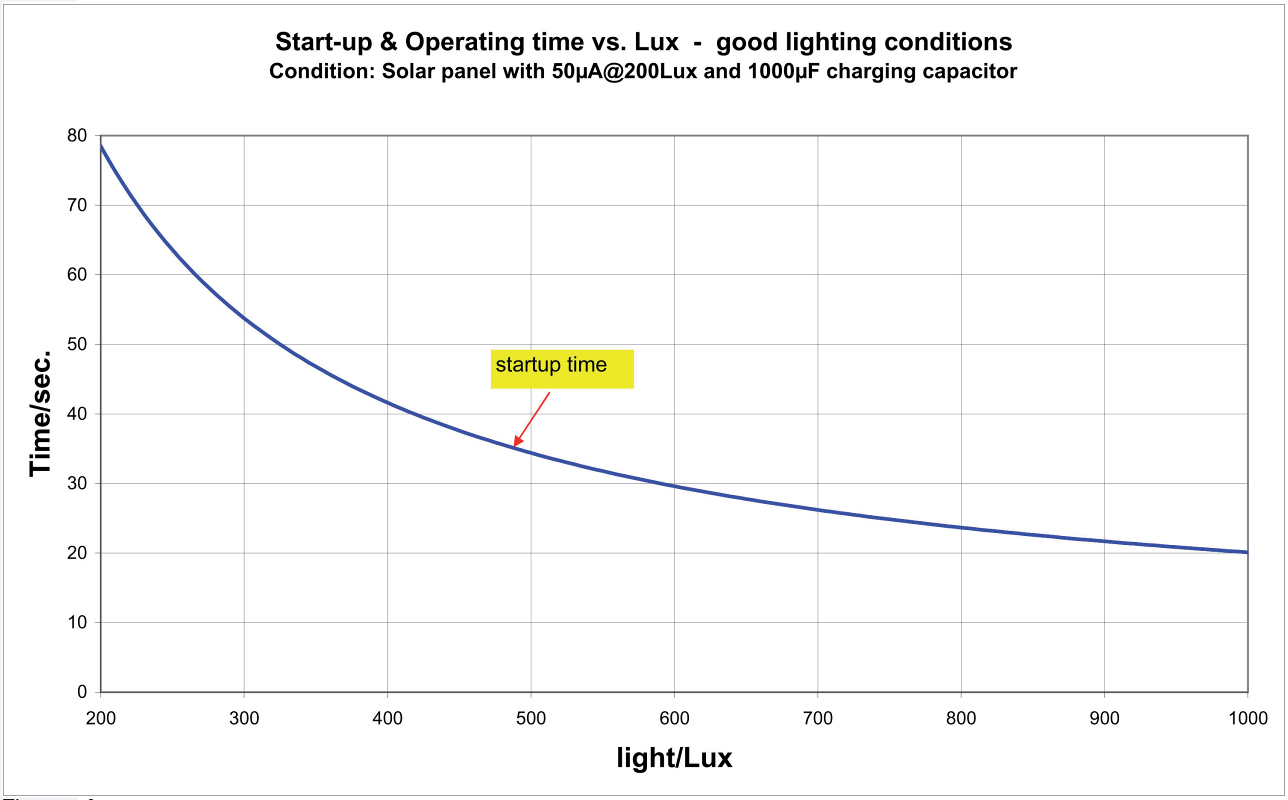


Figure 4

As written before, the startup and operating time of the scale will change if the charging capacitor (C17) is changed and therefore can be adapted to customers need. But: do not reduce C17 below 680µF

4 Remarks to the Schematic

This section describes some of the most important components of the schematics that we provide with this paper. The red, underlined components are critical. Please follow strictly our recommendations for these components. Otherwise a malfunction of the device can occur.
Any component not described herein is less critical or only part of our evaluation PCB (e.g. Battery) and not needed for customers' scales.

Solar Panel

Not part of the schematic. The solar panel has to supply the right voltage. It has to deliver a voltage of > 3.6 V at 3 µA under the minimum required lighting conditions, otherwise the circuit will not start.
We use solar panels from Sinonar, which are amorphous silicon panels with 8 stripes, that fulfill this requirement.

C17

Function: Capacitor to charge the current of the solar panel
Type: Tantalum or Aluminum electrolytic capacitor
Value: ≥ 1000 µF / 6.3 V (min. 680 µF)
Remark: No additional requirements, any standard capacitor with this value can be used. Do not go below 680 µF to avoid malfunction. The minimum value of C17 depends on the capacitor values behind the LDO. Do not increase those capacitors without recalculating C17.

4 Remarks to the Schematic

R7, R14, R10,
Q4, U3, U5

Function : Startup circuit from darkness. Functionality described above.

R7, R14, R10

Normal resistors. **Please use recommended values**.

Q4

Normal NPN transistor, No special requirements.

U3

Function: Power-up detection circuit with Open Drain output
Remarks: A 2.0 V or 2.1 V Type should be used. We have chosen STM1061 because of its low current consumption of 1 µA typical. The current of this part has to be supplied all the time from the solar panel. Any other type with the same functionality can be used, but a higher current has to be taken into the calculation of lighting conditions.

U5

Single Gate 74ACT126 Tri-state Buffer. No special requirements, use available standard types.

U4

Function: Ultra-low quiescent current low-drop linear regulator. The low quiescent current and the low drop are important because they have an impact on the performance. The quiescent current has to be fully factored into the current needed by the scale in all modes. The used XC6206 has a quiescent current of only 1 µA.

A 2.5 V type has to be used. Otherwise, the dimensions of many other components are wrong and a malfunction can occur.

R8, R11, C18

Function: Generate a safe power-on reset to the PS081 when the supply voltage of the PS081 is switched on.
No special requirements on the components. Please use recommended values.

4 Remarks to the Schematic

C1

Function: Load capacitor for the measurement

Type: COG

Value: 150 nF for 1 kOhm standard full bridge
100 nF for half bridge connection (2 kOhm)

Remarks: Very important capacitor. One of the parts that are mainly responsible for the measurement quality. Please use a COG type ceramic capacitor. Other materials (e.g. CFCap) may be also possible, but we have not tested them.

Do not use X7R types (that we have tested). The noise will increase and the stability of the result will decrease to an unacceptable range.

Q1-A ... Q3-B,C5, R12,R6,C6,C3

Q1-A ... Q3-B

PNP bipolar transistors for lowest noise. For Q1-A ... Q3-B please use low noise PNP transistors like 2N5087, BC559, ... These transistor do not need to be matched. We use the double transistor version of 2N5087 which comes in a compact housing.

C3

Function: Blocking capacitor for the comparator

Type: no special requirements

Value: 10 µF

R12,R6,C6

Use standard components, no special requirements

Remark: This comparator needs a special placing and routing on the PCB, please refer to the special section.

C14

Function: Blocking capacitor for Vcc Load.

Type: Tantalum or Aluminum electrolytic capacitor

Value: 68 µF

4 Remarks to the Schematic

Remark: Use 68 µF, do not use a lower value. A higher value may have an impact on C17. For details ask acam.

C7, C16

Function: Blocking capacitors for Vcc-Core

Type: no special requirements

Value: C7 = 10 µF, C16 = 4.7 µF

Remark: Place C7 close to pin 26 of PS081 and C16 close to pin 2 of PS081

R13, C4

Low pass filter to reduce the LF-noise from the LDO. It is important to have a very low cut-off frequency for this filter. Please use recommended values.

R4, R5

Function: resistors for temperature measurement and gain compensation

Type: R4 → 1kOhm metal film resistor

R5 → 1kOhm carbon resistor if RSPAN_BY_TEMP option is used

otherwise also metal film possible

Remarks: R4 & R5 have to be in the same range as the strain gage resistors (normally 1 kOhm). With R4 and R5 the gain compensation of the uncompensated halfbridges can be done using the RSPAN_BY_TEMP options. For more information please refer to the PS081 manual or our application note regarding this item. If no RSPAN_BY_TEMP option is used R5 can also be a metal film resistor

R15

Function: Enables fast oscillator shutdown for current saving

Value: 1 MOhm

Remark: No special requirement, use recommended value, important for current saving.

5 PCB Layout Considerations

Prefix: Three elements are necessary to build a satisfying solar scale:

- PICOSTRAIN
- The right parameter settings
- A good layout

A good double-layer layout is important to get the required measurement quality. Requirements are focused only on a few components and only to a part of the PCB. But don't underestimate the importance of those requirements. Here we give the necessary information for all critical components and also some general information on the layout.

Important Components

Following components have to placed and routed on the PCB under special restriction

- PS081
- R4,R5
- X1
- C7, C16
- C14
- C1
- C3
- C6, R6
- Q1,Q2,Q3
- C5,R12
- R15

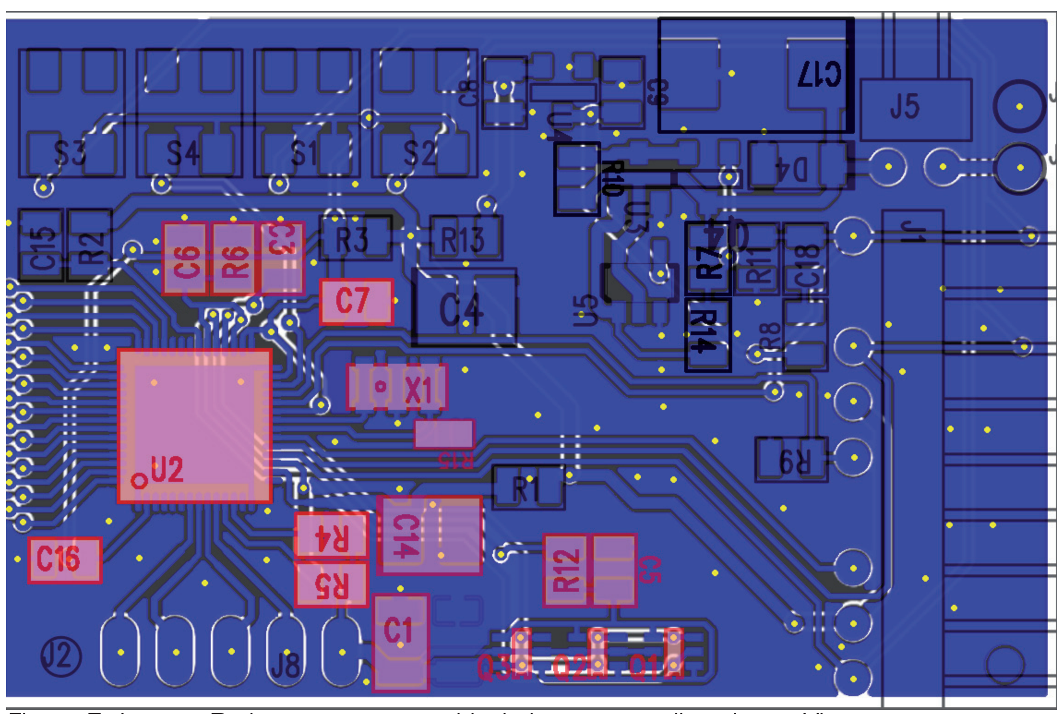


Figure 5: Layout. Red components = critical placement, yellow dots = Vias

5 PCB Layout Considerations

Figure 5 shows a good placement of the critical components. The center of this layout detail is of course the PS081. The parts have to be placed around this component.

PS081 itself has to be placed on the edge of the PCB where the strain gage connections (J8) are placed. Place the strain Gage connections at one edge of the PCB and not in the middle. No other lines should cross the strain gage lines between the connection and the PS081.

R4,R5: Gain compensation and temperature measurement resistors. Therefore part of the strain gage measurement, not very critical, place them close to pins 11 & 12 of PS081

X1: Critical to place, must no be disturbed and must not disturb. Place as close as possible to pins 20 & 21 of PS081. Flood as good as possible a ground plane around the component on both sides of the PCB.
R15: Critical placement. Place it as close as possible to X1.

Q1,Q2,Q3: Critical to place. Place them directly at C1 to minimize the critical load line.

C3: Not very critical. Place it close to pin 32 (UCOMP1) of PS081.

C6,R6: Not very critical. Place them close to pin 31 & 34 of PS081

C5,R12: Not very critical, place them close to Q1, Q2, Q3

C7,C16: Not very critical, but place them as good as possible, C7 close to pin 27 (Vcc-HA) and C16 close to pin 2 (Vcc-Core).

C14: Critical to place. Place it close to pin 16 (Vcc-Load). A good ground plane between C1 and C14 is needed.

C1: Critical to place. Place it close to the Load ports of the PCB. A good ground plane between C1 and C14 is needed.

5 PCB Layout Considerations

Additional Hints:

Normally the Load line is the most critical one. But with above recommended placement the load line can be reduced to a few millimeters and is therefore easy to route.
The new critical line (but not as critical as the Load line) is the connection between the collectors of Q1, Q2, Q3 and pin 34 (Stop) of PS081.

For this line we can give the following recommendations:

- Do not cross X1 with this line on any layer
- Do not cross the SG Ports (pin 3 … pin 11) of the PS081 with this line
- Make a ground plane around this line on both layers as good as possible

Ground plane: A good ground plane is very important for good measurement results. Because of commercial reasons only a double layer can be used. Therefore, it is very important to do the best for a good grounding of the critical components.
Our recommendations are:

- Flood the empty space on **both** sides of the PCB with ground
- Connect both ground planes with vias (see yellow dots) on several places on the PCB
- For longer lines (e.g. Load Line) that “cut” the ground into 2 stripes, “shortcut” these ground stripes on the other layer

If these hints are followed, the possible measurement results of such a double layer PCB are very close to those of a multilayer PCB and good enough for a solar driven scale which has, because of its highly pulsed operation, high requirements on a good layout.

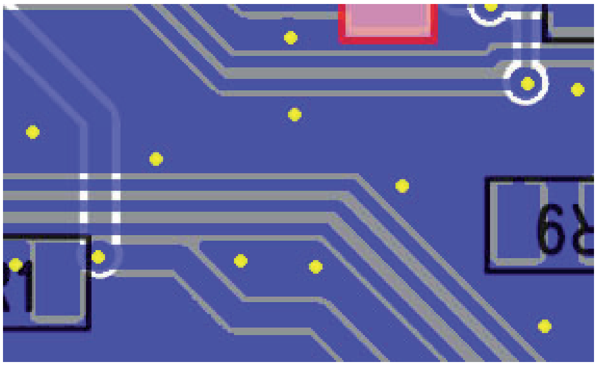


Figure 6: Yellow dots = Vias connecting ground planes

6 Parameter Settings

6.1 Important Parameters

Our PICOSTRAIN devices can be used in many different applications like

- Solar driven scales down to 15 µA total operating current
- High resolution scales up to 250,000 scale divisions
- Legal-for-trade scales up to 10,000 divisions OIML

Therefore, our PICOSTRAIN chips have several configuration registers where the device has to be set in the proper operating condition for the special application.

With this application note we provide an application software which sets all these registers to the right value. Nevertheless, we want to give here a list of register settings that are very critical and that have to be used according to our recommendations.

The solar kitchen scale software is based on an auto-on scale with automatic zero tracking. In Off mode the scale scans permanently (once per second) the strain gage sensors with low resolution (approx. 10 g peak-peak). Additionally, the offset of the sensor is measured frequently (once in 5 minutes) with full resolution. If a weight is detected in scan mode the scale switches on automatically and measures with an update rate of 3 Hz and 1 gram peak-peak resolution.

This application software is not a fully completed software for 'real' kitchen scales. The purpose of this software is to give the necessary basics for own software developments. Because of the Auto-On capability we have 2 modes

- Scan mode
- Measure mode

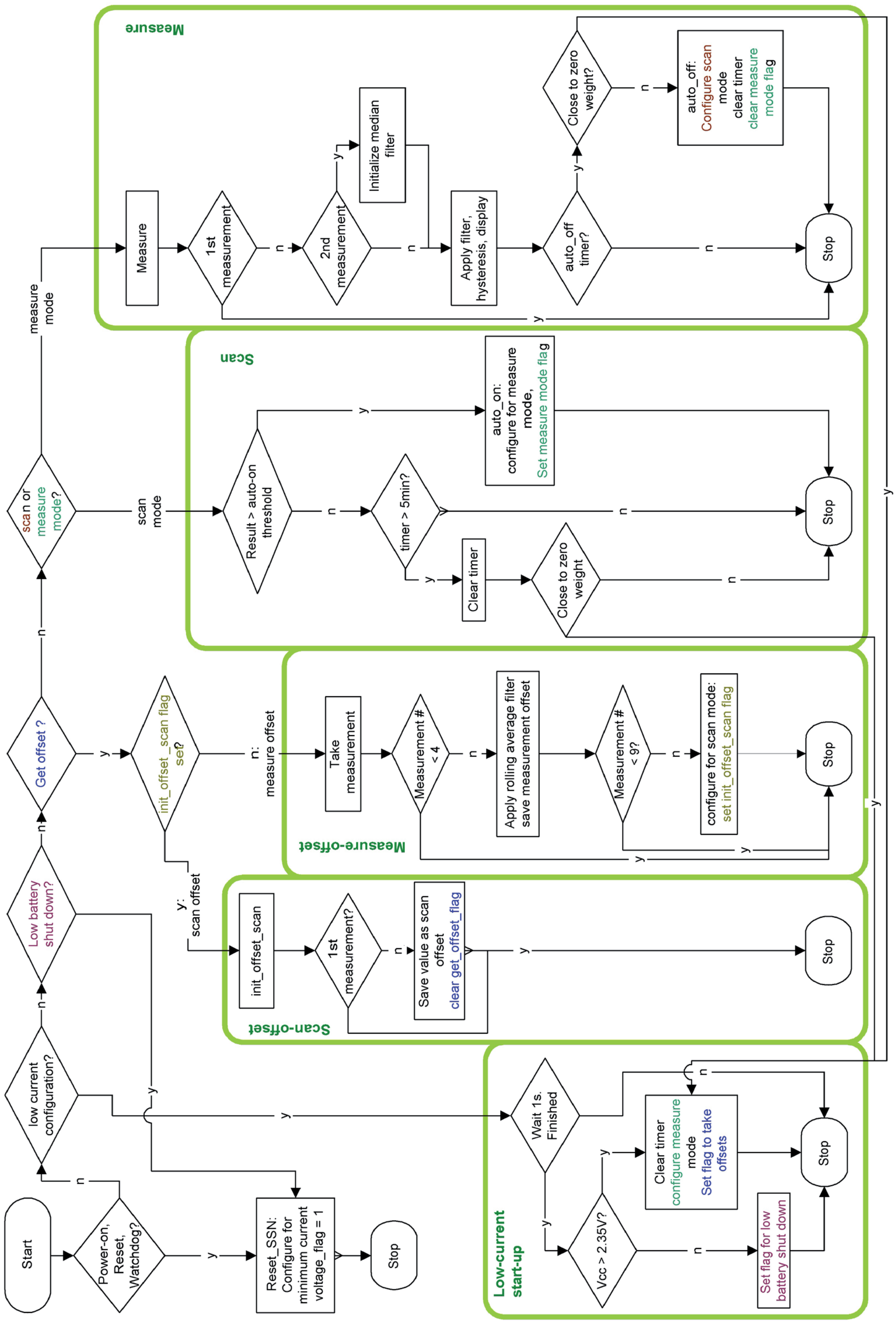
For both modes it is important to have the proper parameter settings for a good operation. In the following table we give you the relevant settings for both modes. Parameters that are not described can be set according to customers' request or default values can be used. A sample setting for all parameters can be found in our application software.

6 Parameter Settings

Parameter	Register	Bit	Mode		**Remark**
			Measure*	**Scan***	
Cycle Time	2	4..13	180	550	3 Hz measure, 1 Hz scan
AVRate	2	14..23	8	2	Value for 5,000 divisions
bridge	3	0..1	2	1	2xHB measurement, 1xHB scan
con_comp	11	0..1	1	1	
sel_compr	0	14..15	3	3	
sense_discharge	16	10	1	1	
single conversion	2	2	0	0	
mfake	3	2,3	0	0	
sel_start_osz	3	17..19	3	3	200 µs startup time for oscil-lator
stretch	3	12..13	2	2	Stretched Mode HB 200 µs
dis_osc_startup	0	3	1	1	Set to 1 or noise increase
ps081adjust	3	4..9	16	16	Important noise setting
pptemp	2	3	1	0	No compensation in scan mode
mult_en_pp	1	7	1	1	Use gain compensation and temperature measurement
mult_pp	10	0..7	164	164	Recommended 1.28 (real)
dis_noise4	3	14	1	1	
lcd_directdrive	16	19	1	1	Use direct drive for LCD
rspan_by_temp	1	8	1	1	Enable rspan_by_temp option if an un-compensated load cell is used
mod_rspan	1	6	1	1	Enable mod_rspan
mult_tkg	8	0..23	´h100000	´h100000	1.0 = default, depends on the strain gage used
mult_tko	9	0..23	0	0	Use default

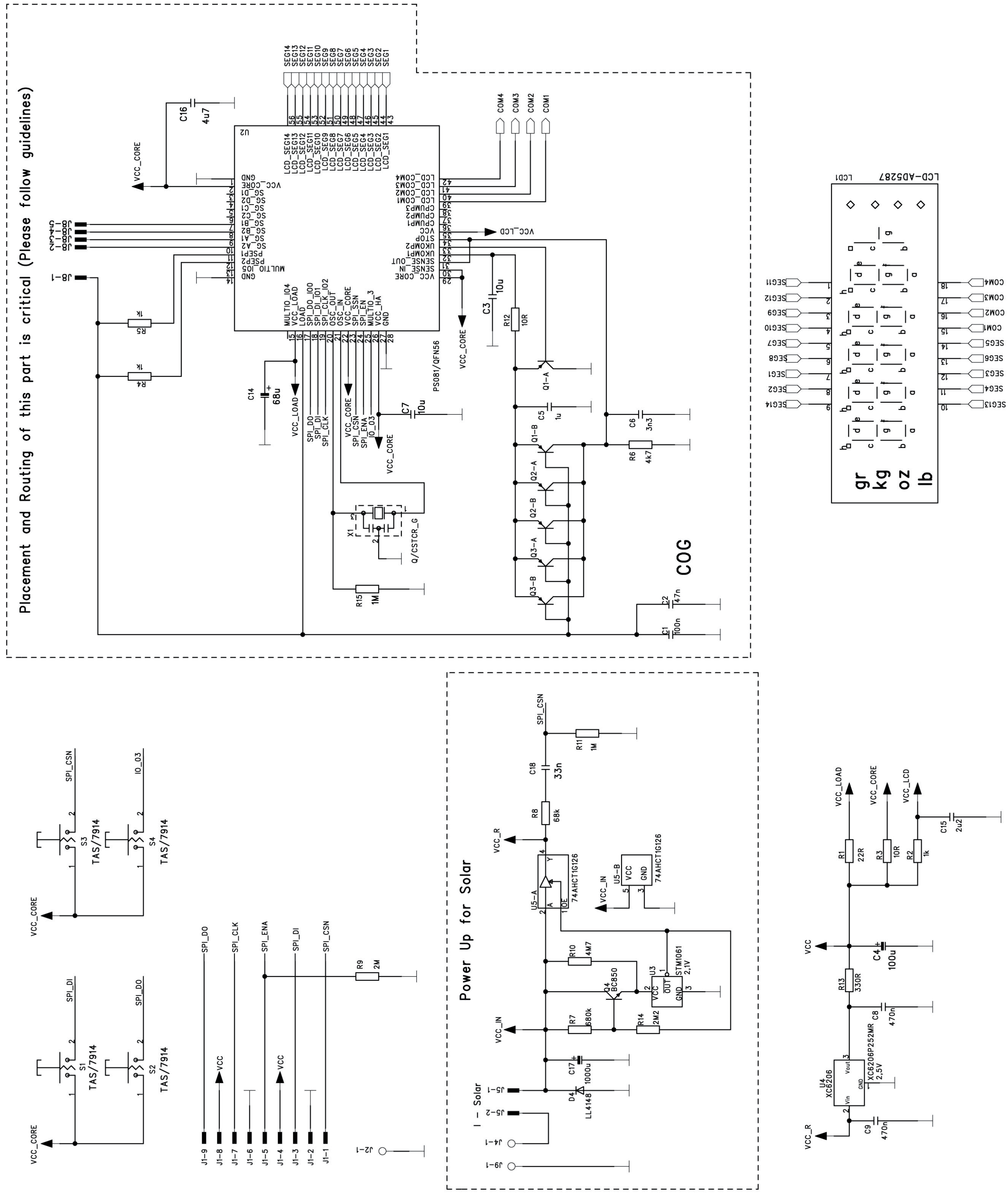
*All values decimal
Red = difference between both modes

6.2 Programs's Structure (Flowchart)



7 Appendix

7.1 Schematics



7 Appendix

7.2 6.2 PCB Layout